2^{nd} Semester Report

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PhD Program: Particle and Nuclear Physics
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PhD Thesis Title: Analytical and Simulation Methods of Detector Physics in High Energy Experiments

Introduction

In my previous report I described how I preliminarily compared Geant4 simulations and measurements on pion- and muon-enriched beams via a purpose-written tracking algorithm, as part of the ALICE 3 MuonID project. In this semester, I continued this work in order to decide on the optimal absorber length and technology to be used for the ALICE 3 muon detector system.

Description of research work carried out in current semester

Geant4 simulations:
Using the Geant4 models I developed previously, I worked on adjusting the simulations to the measured data. This included comparing the energy deposition distribution in the simulations to the ADC signal of the MWPC detectors and matching them, as well as adjusting the energy threshold of detection in order to simulate the efficiency of the chambers. The beam profiles after the absorber from the measurements and simulations have been compared to show high agreement, demonstrating the predictive power of the simulations. Furthermore, the composition of the scattered beam has been analyzed to determine the feature of the showers and characterize the nature of the particle background that acts as noise in our measurements (most importantly, delta electrons). Additionally, Geant4 simulations are being prepared for the simulation of planned measurement configuration for the ALICE MuonID 2025 experiment (see below).

Hadron suppression evaluation:
Using the tracking algorithm I developed and discussed in my previous report, I was able to partially filter the measurement data to analyze individual events, although additional filtering was required on the measured ADC signal due to possible noise in the data acquisition system. One of our measurements (taken at a 90 cm absorber) turned out to have been taken at a collimator setting producing a magnitude larger intensity than our nominal ”high intensity” measurements. Correction of this data was attempted based on the number of discarded trigger decisions as supplementary information, but to no avail, hence that data had to be thrown away. The correlation of hits in each chamber has been calculated, determining the most probable hit location in each chamber (given a hit was recorded in another chamber). Using these results, a quantity

$\chi^2 = \left(\frac{\text{Distance of hit from expected position}}{\text{Width of expected hit position peak}}\right)^2 + \left(\frac{\text{Distance of hit from the beam center}}{\text{Width of all hit position peak}}\right)^2$ was calculated for each hit pair in the detectors in order to tag muons and to determine the signal ratio in pion-enriched measurements, alongside a 95% muon acceptance. Comparison with simulations shows a (78$\pm$2)% muon content in the muon-enriched beam, while an approximately (2.0$\pm$0.2)% muon contamination in the pion-enriched beam. Further reduction of pion background using machine learning (CNN architecture) trained on simulations is work in progress.

CERN ALICE MuonID 2025 test beam measurement:
Between July 30, 2025, and August 13, 2025, another test beam measurement is scheduled. The goal of this measurement is to repeat some of the measurements from last year that was deemed unusable, and test larger MWPCs (120 cm $\times$ 80 cm, 12 mm segmentation) with characteristics more similar to the chambers to be proposed in the final design of the ALICE 3. Additionally, a magnet is proposed to be installed in the beamline for better beam energy distribution determination.

Publications

A joint publication with the Mexican team is in progress (scheduled for submission June, 2025), as well as a standalone publication is also in the works. Also, results of ongoing analysis were presented on 2 separate ALICE 3 Days events on February 14, 2025 and May 20, 2025.

Studies in current semester

1. Experimental Methods in Particle Physics (FIZ/2/138)
   Grade: 5 (Excellent)

2. Experimental Methods of Nuclear Physics (FIZ/2/022)
   Grade: 5 (Excellent)

3. Advanced Machine Learning Lab (FIZ/3/093)
   Grade: 5 (Excellent)

Teaching activity in current semester

1. Classical Physics Laboratory (fizlab2f19la)

2. Numerical Methods in Physics II. (fiznum2f19la)

3. Python-based Problem Solving in Physics (EJC-MATFIZ-KUT/04)

Professional activities

Throughout the semester, I participated in multiple events promoting science such as ”Múzeumok Majálisa”, and gave physics lectures in science schools such as ”Eötvös József Tehetséggondozó Tábor”, while another lecture is planned in this year’s ”Eötvös Természettudományos Tábor”, where I serve as one of the main organizers.